Handling device for preparing a wafer stack

The invention relates to a handling device for wafers (semiconductor disks) or other disk-like substrates, which has a storage device in which a plurality of wafers can be arranged with their surfaces aligned substantially parallel to one another, one behind another and outside a transport container, and is provided with a gripping device with which individual wafers can be removed from the storage device and/or inserted into it. The invention additionally relates to a gripping device, a storage device and a method according to the preambles of claims 9, 10 and 12.

The basis for the production of electronic components is, for example, semiconductor disks, wafers as they are known, or LCD glass substrates preprocessed in a specific way. For their surface processing, they have to pass through various process stages. Here, raw wafers (unprocessed wafers) are produced and, as a rule, are stored temporarily in transport and preserving containers between passing through individual process stages. For the actual processing process, these unprocessed or only partly processed wafers have to be removed from the container, supplied to a device for carrying out the processing process and subsequently deposited in a container again. The number of wafers provided in a container is also referred to as a "batch" (stack). The batch size is standardized and is usually 25 (or 13) wafers.

A fundamental problem in the entire processing and temporary storage is that the wafers have to be kept away from contaminants and dirt. Even extremely small contaminations caused by dust or other particles produce damage to the corresponding region of the wafer surface. This can lead to considerable reject rates of the end products produced from these wafers. The

processing is therefore normally carried out using clean-room technology, as it is known, that is to say the processing zones must exhibit a specific, defined purity in relation to these dirt particles. Of course, the same also applies to the temporary storage, that is to say the preserving containers.

It has been shown that qualitative difference can arise in wafers from a batch if they always pass through the individual process stages in the same order. It may therefore be advantageous for the order of the wafers within a batch to be changed. In order to arrange wafers at different points in a batch, devices have already been disclosed in which a gripping device designed as an individual gripper in each case removes a wafer from a batch arranged in a cassette and deposits it in another cassette - or another holding device - at a different cassette location. The batch is assembled for the next process as soon as the individual grippers have in each case removed all the wafers individually and deposited them at a predetermined point in the other cassette. However, this device has the disadvantage that the assembly of the batch takes up a relatively large amount of time. In addition, with this device it is hardly possible to assemble a new batch from different batches.

For example, handling devices for wafers are also previously known from EP 0 496 006 A1 and US 4,695,217, which each have two holding rollers which are arranged parallel to each other and can be rotated about their respective longitudinal axis. The holding rollers are provided with slots running along the circumference of each holding roller. By means of the two holding rollers, each wafer of a wafer stack can thus be held by being arranged in a respective slot in the two

holding rollers. In addition, the holding rollers have regions with a low radial extent. If these regions of each holding roller are brought, by means of rotation of the holding rollers, into a position in which the regions lie opposite one another, then a wafer stack can be led through between the holding rollers, for example in order to append another wafer stack already arranged on the holding rollers. However, this type of previously known handling devices has the disadvantage that it permits only the handling of already existing wafer stacks.

The invention is therefore based on the object of providing a device with which a stack of wafers to be processed can be assembled as efficiently as possible in any desired but predetermined order.

In a device of the type mentioned at the beginning, the object is achieved by the gripping device having a plurality of grippers which can be moved together but can be actuated independently of one another, it being possible in each case for at least one wafer to be gripped and/or inserted into the storage device as a

result of the actuation of a gripper. This makes it possible, as compared with previously known generic devices, to considerably shorten the travel distances required for the assembly of a wafer batch.

The handling device according to the invention can make it possible firstly to grip a plurality of wafers with a plurality of individually actuated grippers and to remove them from the storage device and only then to insert these wafers, together, preferably into another storage or holding device. The travel distance between the storage device and the holding device can therefore be shortened to a greater extent the more wafers the gripping device can pick up with individually actuated grippers, before it transfers these to another location on the holding device. Therefore, as early as during the removal from the storage device, the wafers should be arranged in the gripping device in the order which they are also intended to have in the holding device or for the next process. This may be achieved particularly simply if, via a control system of a handling device according to the invention, it is possible to choose freely which wafer is gripped by which gripper.

In a preferred embodiment, the number of grippers present in a gripping device can correspond to the number of wafers in a wafer batch. The grippers can therefore be designed in such a way that compaction of a wafer stack can also be carried out. Compaction is to be understood to mean that one or more wafers from one or more other batches are to be inserted in each case between two wafers from a first stack or batch. However, compaction can also be understood to mean that the distance between successive wafers in the wafer stack to be created is smaller than in the initial stack. By this means, with the same space requirement, a larger number of wafers can be processed. Such compaction is often desirable in order to increase the

economy of process systems, by processing more than one wafer batch at the same time.

Although it is preferred for one gripper of a handling device according to the invention in each case to be able to handle only one wafer, depending on the requirements placed on the handling device provision could also be made for at least one gripper which can pick up a plurality of wafers to be provided among the plurality of mutually independently actuable grippers.

An embodiment of a gripping device according to the invention which is particularly uncomplicated in design terms can provide, for grippers to be pivoted into two end positions in a first end position, namely an empty position of the gripper, no wafer being located in the gripper, and in a second end position, a transport position for wafers, a wafer being arranged in the gripper. In order to remove a wafer from the storage device, the corresponding gripper has to be transferred from its empty position into its gripping position. During this movement, the gripper grips the wafer and guides it out of the storage device. Conversely, during the movement from the transport position to the empty position, the gripper passes on the respective wafer to the storage device. During the movement of the gripper device along the storage device, each of the grippers is located in one of the two end positions.

A further expedient refinement of the gripping device can provide for grippers belonging to the gripping device to be capable of moving at least approximately rectilinearly, that is to say translationally, individually, independently of other grippers, and substantially parallel to the surfaces of the wafers and transversely with respect to the travel direction of the gripping device. In this embodiment, too, each gripper belonging to the gripping device can be

transferable into an empty and into a gripping position and, in this case, can carry out the same functions as the embodiment provided with pivotable grippers.

The object is also achieved by a storage device for temporary storage of wafers, which has a housing which forms an interior space in which there are a plurality of storage locations for transport containers of wafers, which is provided with a manipulator which handles the transport containers, at least part of the interior space being designed as a clean-room area, in which wafers can be handled outside transport containers and stored temporarily in a storage device and which has at least one gripping device according to the invention in the interior space.

The invention thus makes it possible to increase the functionality of storage devices considerably. It is then possible to store transport containers with a wafer batch in the storage device and to remove the same storage container with a completely differently assembled wafer batch arranged therein, which can be supplied immediately to a process system for further processing. Hitherto, should the order of the wafers in a wafer batch have to be changed or individual wafers in the batch have to be exchanged, this had to be carried out in a separate system. This needed additional storage area. Since, in semiconductor works, storage area is particularly expensive on account of the clean-room conditions to be created in each works, as a result of the integration of the gripping device according to the invention, the storage area required overall can advantageously be reduced.

A further aspect of the invention relates to a method of assembling a wafer batch as indicated in claims 12 or 13. In the case of previously known methods, provision is made that, in one cycle, firstly in each

case a wafer is removed by an individual gripper from a wafer stack arranged in a storage device and is arranged in a holding device. This cycle is repeated with other wafers, always using the same gripper, until the wafer batch has been assembled. Turning away from this, in a method according to the invention, provision can be made that firstly a plurality of wafers, preferably a complete wafer batch, is removed from the initial wafer stack one after another by a gripping device. Only after a plurality of wafers have been removed one after another by the gripping device are the wafers passed on by the gripping device, preferably simultaneously, to the storage device or to a holding device differing from the latter.

In order to carry out the method according to the invention, an initial wafer stack can be arranged in the storage device, having a number of wafers which preferably corresponds to a multiple of the wafer batch to be created. However, it is of course also possible to carry out the method when the number of wafers in the initial stack corresponds at least to the number of wafers in the wafer stack to be created.

With the method according to the invention, the time required to assemble a wafer batch can be reduced considerably.

Further preferred refinements of the invention emerge from the dependent claims.

The invention will be explained in more detail using the exemplary embodiments illustrated schematically in the figures, in which:

Fig. 1 shows a perspective illustration of a storage device according to the invention;

Fig. 2 shows an outline representation of the storage device shown in Fig. 1;

Fig. 2a shows a side view of the storage device according to the invention from Fig. 1;

Fig. 3 shows a very schematic perspective illustration of a gripping device according to the invention arranged in front of a storage device, shown in part;

Fig. 3a shows a very schematic perspective illustration of a gripping device according to the invention arranged in front of a transfer station;

Fig. 4 shows an individual gripper of the device from Fig. 3 in a gripping position;

Fig. 5 shows two end positions of the gripper from Fig. 4;

Fig. 6 shows a front view of a further exemplary embodiment of a gripping device, in which a gripper is shown in two different end positions.

Figures 1 and 2 show a storage device 1 (a "stocker") for wafers. An interior space, in which clean-room conditions prevail, is formed by a housing 2 of the storage device 1. The storage device 1 has two airlock locations 3, 4, at which transport containers for wafers can be positioned for the purpose of input or output to and from the storage device. Transport containers can be closed boxes or open cassettes. At the airlock location 3 there is a transport device (not illustrated), with which a transport container 6 can be introduced into the interior of the storage device 1 by opening an airlock door 5 or can be guided out of the

storage device 1. Immediately opposite the airlock locations 3, 4 there are five storage lines 7, 8, 9, 10, 11 arranged approximately in a semicircle in relation to one another. Each of the first four storage lines has a specific number of storage locations arranged one above another for transport containers 6. The fifth storage line 7 has one storage location less than the other storage lines, since in the region below it, the wafers arranged in a transport container 6 are passed on by a transfer module from the stocker to a system 16 for handling wafers. A manipulator which can be moved in the vertical direction (Z axis) and is designed as a bending-arm robot 14 handles the transport containers 6 by setting the transport containers from the airlock door 5 down in a storage location or transferring them from the latter to the airlock door 5.

The system 16 for handling a wafer batch is provided on a wall surface 15 of the storage device 1 located opposite the airlock door 5. In this case, this is substantially two rollers 17, 18 which are aligned parallel to each other and on whose circumference holders (not specifically illustrated) for holding the wafers in a vertical position are provided. The wafers are passed on by means of a vertically movable batch gripper from the transport container to the horizontally movable rotors 17, 18 and there are inserted into holders.

The rollers can be moved together in the Y direction, in order to arrange the wafers in one of four stations illustrated by dots. In each station, there is a holding rake (not specifically shown) which can be moved vertically (Z axis). Each of the holding rakes can accept the wafers from the rollers 17, 18 or pass them on to said rollers 17, 18 by being moved vertically between the latter. The construction and the

functioning of such a system is described in the European patent application number 97 115 686.4 dated September 10, 1997 from the applicant, whose content is incorporated completely by reference.

The first station 19 is used to pass on the wafers from a transport container to the rollers. For this purpose, in the region identified by the designation 20 (figures 2, 2a) the transfer module is provided [lacuna] a system with which the wafers can in each case be removed from the lowest transport box in the storage line 7 by means of a batch gripper and passed on to the rollers 17, 18. A system with which this can be carried out is shown in the European patent application number 97 107 352.3 dated May 3, 1997 from the applicant. The content of this application is hereby also incorporated completely by reference.

The second station 21 is used to align the wafers in relation to their rotational orientation about a longitudinal axis 22 of a batch 23, and for detecting erroneous positioning of the wafers in the holding rake. The rotational position of each of the wafers is determined by detecting a notch present on each wafer. As a further function, a camera 24 is incorporated, which monitors the number and the position of the wafers.

The third station 25 is provided with a gripping device 28, which has 25 individual grippers that can be actuated individually and independently of one another. All the grippers are fixed to a common carrier such that they can move. The storage device, formed as the holding rake of this station, can additionally also be moved linearly in the X-direction, parallel to the wafer batch and the rollers, with respect to the fixed-position carrier. The travel distances of the holding rake are integer multiples of the distance between the

wafer holders arranged beside one another in the holding rake. In order to make it possible for each gripper inherently to be able to pick up each wafer from the holding rake, the total travel distance of the holding rake should correspond to twice its length. The possible design construction of such a gripping device will be explained in more detail below.

With the gripping device 28, a specific wafer can be removed from the holding rake by a gripper in each case. By means of a relative movement between the holding rake and the gripping device, parallel to the batch axis 22 (stack direction), another gripper is subsequently arranged opposite the wafer now to be removed and the wafer is guided out of the holding rake. This is carried out until all the wafers in the batch have been gripped by the gripping device. The wafers are then inserted into the holding rake again by the gripping device. One possibility for doing this is for all the wafers to be inserted into the holding rake by their gripper at the same time. Should the position of one or more wafers remain unchanged, provision can of course also be made for these wafers to remain in the holding rake and for only the wafers to be exchanged to be removed.

Alternatively, provision could also be made for the individual grippers - preferably all the grippers - each to pick up a wafer simultaneously but to insert the wafers one after another at points of the holding rake which are now different. If the result is that, in a specific position of the gripping device with respect to the holding rake, a plurality of wafers can be set down in their new positions in the holding rake, then the corresponding at least two grippers can also be actuated at the same time.

During these procedures, a new order of the wafers can

be produced, it being possible for the new order to depend on which gripper removes which wafer from the holding rake or inserts it at which point in the holding rake. In order to keep the travel distances of the holding rake as short as possible, the respective next gripper used should always be that gripper whose wafer to be gripped in the current position of the gripping device has the shortest distance from the gripper assigned to it. Which wafer is to be gripped by which gripper can already be defined in advance by means of a predefined order. However, it can equally well be possible for the order to be determined by a random generator.

The fourth station 40 is located at one end side of a handling device 41 for wafers, in which wafers are temporarily stored outside transport containers 6 or transport cassettes. In addition, with the handling device 41, wafer batches are assembled from the several hundred wafers, for example 600 wafers, arranged with their surfaces vertical and parallel to one another in a storage device 42.

Provided for this purpose is a gripping device 43, which can be constructed in substantially the same way as the gripping device 28 of the third station 25. Figures 3, 4 and 5 show a first exemplary embodiment of such a gripping device 43 according to the invention. This has a total of 25 identical grippers 44, which are pivotably attached to a carrier 45. Each gripper 44 is provided with an arc-shaped pivoting arm 46. An inner edge 47 of the pivoting arm 46 is of circular arc configuration, extends over an angular range of about 200° and has a radius that is slightly greater than the radius of a wafer 48 to be gripped. Provided at a free end of the pivoting arm 46 and in the region of the attachment of the pivoting arm 46 to the carrier 44 is a holding element 49, 50 in each case. The two holding

elements 49, 50 in each case project beyond the inner edge 47 and - in relation to the arc of the pivoting arm formed by the inner edge 47 - are located more than 180° apart. Furthermore, approximately at the center between these two holding elements 49, 50, a passively actuable further holding element 51 is fitted which, in its end position, likewise projects beyond the inner edge 47. The three holding elements 49 - 51 lie on a common (imaginary) plane. They each have on their circumference a circumferential groove (not shown), which is provided to hold a wafer 48.

Figure 5 shows the two end positions which the pivoting arm 46 of a gripper 44 can assume. In order to achieve an individual movement in the case of each gripper, different design solutions can be provided, whose basic construction will be explained briefly below. In a first configuration, the gripping device has a central drive for all the grippers, the individual grippers being actuated via selectable clutches. In a second possible configuration, each gripper is provided with a separate drive, for example a very narrow electric "voice-coil motor". Each of these drives can also be selected separately. Finally, it is also possible to actuate each gripper via individual cylinders which, for reasons of space, can also be arranged to be offset in relation to one another.

In the first lower end position, the pivoting arm 46 is located in an empty position of the gripping device. In this position, the gripper is arranged at a distance from the wafers located in the storage device 42. The holding elements 49, 50 and 51 are also at a distance from the wafers, so that the gripper 44 can be moved along the X-axis, parallel to the storage device, without collision.

In order to remove a wafer from the storage device, the

gripper with its pivoting arm 46 firstly has to be arranged in a plane in the X direction which is aligned with the plane formed by a wafer. Then, in relation to the representation of figure 5, the pivoting arm 46 can be transferred in the counterclockwise direction into its transport position. As soon as immediately after the start of this pivoting movement, the holding elements 49, 50 come into contact with the wafer below a diametrical line 54, which runs parallel to a connecting line 53 between the two contact points of the holding elements 49, 50. As a result, the wafer is gripped and lifted by the gripper. Immediately thereafter, the holding element 51 is actuated passively - for example by a cam disk or a stop - as a result of which the latter is brought up to the wafer and rests against the side edge of the latter. As a result, the wafer is fixed in the gripper and, without executing relative movements with respect to the wafer, is carried along by the latter into the transport position. During its movement from one end position into the other, the pivoting arm pivots through about 75°. In the transport position, as well, the gripper - and of course also the wafer located therein - is arranged at a distance from the storage device and its wafers. Thus, even in this end position, the gripper 44 can be moved along the storage device in the X direction without collision.

As soon as the pivoting arm 46 has reached the transport position, the gripping operation is concluded. The gripping device can then be moved parallel to the wafer stack (in the X direction), that is to say in the stack direction of the wafers, in order to use another gripper to remove the next wafer from the storage device 42 in basically the same manner. This is repeated with respectively further other grippers until all the wafers to be gripped have been removed from the storage device and are arranged

in the gripping device.

After one of the grippers with the last wafer to be gripped has been pivoted into its moving position, the gripping device can be moved to the transfer station, whose holding rake 37 has holders for all the wafers in a wafer batch. The wafers arranged in the gripping device are then passed on to the holding rake 37. For this purpose, the gripping device is first of all arranged beside the holding rake, so that each wafer is aligned with a holder in the rake. Then, all the pivoting arms 46 holding a wafer 48 are pivoted simultaneously from their transport position into their empty position. At the end of the pivoting movement, the wafers are in each case arranged in a holder and are located outside the grooves in the holding elements 49, 50. During this movement, the holding element 51 is also pivoted back into its release position by passive actuation. This procedure is shown in figure 3a.

By means of lowering the holding rake, the newly assembled wafer batch can now be passed on to the rollers 17, 18 which have been arranged underneath it until now and which subsequently transfers the batch to one of the other three stations for further treatment.

A wafer batch which is brought by the rollers 17, 18 into the transfer station 40 can be inserted into the storage device in the opposite order from the transfer station. For this purpose, first of all all the wafers 48 in the batch are gripped simultaneously by one of the grippers and in each case pivoted into the transport position. Then, each gripper in the gripping device is positioned in front of a holder in the storage device and the respective wafer is passed on to the storage device. In this case, the wafers can be inserted into the storage device at the same time, as entire batch, or individually one after another. Of

course, it is also possible to pass on to the storage device 42 at the same time a number of a plurality of wafers which is smaller than a batch. In this case, the remaining wafers have to be subsequently inserted into the storage device - again simultaneously or jointly in groups. Irrespective of the order in which the wafers are inserted into the storage device the position in the storage device at which each wafer is inserted is stored in a memory of a control system (not illustrated) belonging to the handling device. In addition, for each wafer information can also be stored as to which processes it has previously passed through in which position in the batch and which processes still have to be completed.

In figure 3, adjacent holders of the storage device 42, of which only part of the length is shown in this illustration, have a spacing which is smaller than the usual spacing of wafers in transport containers ("pitch"), and than the spacing between adjacent pivoting arms belonging to the gripping device. For example, the spacing of the holders can be, for example, half or one third of the usual pitch. Should all the adjacent holders be filled, it is therefore necessary for the gripping device in each case to insert one or more further wafers between two wafers already located in the storage device. As a result, compaction of the wafer stack arranged in the storage device can be achieved, as a result of which the length of the storage device needed for a specific number of wafers can be reduced.

The gripping device according to the invention can also be constructed in design terms in a different way than that shown in figures 3 to 5. As figure 6 shows, for example a gripper 60 of a gripping device according to the invention can also be capable of being moved linearly in the Z direction, in order to transfer a

gripper 60 from its empty position into its transport position and vice versa. In the exemplary embodiment shown, a carrier 61 is provided, which can be moved linearly and in the X direction, parallel to the wafer stack and the storage device 42, on a guide rail 62 arranged under the storage device 42. The carrier 61 reaches around the storage device and, on both sides of the storage device 42, has a telescopic gripping arm 63, 64 which can be moved vertically and runs along a vertical line. At a free end of each gripping arm 63, 64, a gripping element 65, 66 that points toward the other gripping arm is in each case provided, and is provided with a groove to hold a wafer 48. The two gripping arms 63, 64 of a gripper execute all movements simultaneously and synchronously. The gripping device can have a number of grippers 60 which are constructed in this way and can be actuated independently of each other, said number corresponding to the largest wafer batch to be handled. The actuation of the grippers can be performed, for example, by means of individual pneumatic cylinders, by means of individual voice-coil motors or by means of a central motor that can be coupled separately to each gripper. In the case of this exemplary embodiment, too, all the grippers 60 can be moved simultaneously, linearly and parallel to the longitudinal extent of the storage device (X direction).

The grippers can be moved jointly in the X direction into both end positions. In a lower, empty position, shown by continuous lines in figure 6, the two gripping elements are located underneath a horizontal diametrical line 67 of the wafers 48, so that the gripping elements 65, 66 are arranged at a distance from the wafers. If the gripper is arranged with its gripping elements 65, 66 in the X direction at the position of a wafer 48, and if the gripping arms 63, 64 are transferred from the lower to the upper end

position, then in this case the respective wafer is gripped and guided upward out of the storage device. In the upper movement position the respective wafer 48 is arranged in relation to a Z direction at a distance from the wafers located in the storage device 42. Thus, each gripper can be moved in the X direction, parallel to the storage device, in its two end positions.